Claims

WHAT IS CLAIMED IS:

1. A method comprising:

generating derivatives of a nonlinear invariance transformation at a training data point with respect to a transformation parameter, the training data point representing one of a plurality of training patterns; and

generating a classifier representation based on the derivatives for classifying a test pattern in the presence of the nonlinear invariance transformation.

2. The method of claim 1 further comprising:

classifying the test pattern based on the classifier representation.

3. The method of claim 1 further comprising:

receiving the plurality of training patterns; and

characterizing one of the training patterns to provide the training data point.

4. The method of claim 1 further comprising:

classifying the test pattern based on the classifier representation to provide a classification signal; and

inputting the test pattern to the operation of generating derivatives as a training pattern, responsive to the classifying operation.

5. The method of claim 1 further comprising:

classifying the test pattern based on the classifier representation to provide a classification signal;

inputting the test pattern to the operation of generating derivatives as a training pattern; and

inputting the classification signal to the operation of generating derivatives in association with the test pattern.

6. The method of claim 1 wherein the non-linear invariant transformation is represented by a Taylor expansion polynomial.

7. The method of claim 1 wherein the nonlinear invariance transformation models a rotation of an individual training pattern.

8. The method of claim 1 wherein the nonlinear invariance transformation models a sheering in an individual training pattern.

9. The method of claim 1 wherein the nonlinear invariance transformation models a translation in an individual training pattern.

10. The method of claim 1 wherein the nonlinear invariance transformation models a change in lighting angle in an individual training pattern.

11. The method of claim 1 wherein the nonlinear invariance transformation models a change in brightness in an individual training pattern.

12. The method of claim 1 wherein the nonlinear invariance transformation models a scaling of an individual training pattern.

13. The method of claim 1 wherein the nonlinear invariance transformation models a change in line thickness in an individual training pattern.

14. The method of claim 1 wherein the nonlinear invariance transformation models a change in frequency composition of an individual training pattern.

15. The method of claim 1 wherein the nonlinear invariance transformation models a change in duration of an individual training pattern.

16. The method of claim 1 wherein the test pattern includes an image.

17. The method of claim 1 wherein the test pattern includes an audio input.

18. The method of claim 1 wherein the test pattern includes a handwriting pattern.

19. The method of claim 1 wherein the test pattern includes a time series.

20. The method of claim 1 further comprising:

restricting a range of the transformation parameter to a closed interval on a line of real numbers.

21. The method of claim 1 further comprising:

representing a scalar product of the classifier representation with the derivatives of the nonlinear invariance transformation at the training data point with respect to the transformation parameter by a nonlinear positive definite real-valued kernel function.

22. The method of claim 1 wherein the operation of generating derivatives comprises:

generating derivatives of the nonlinear invariance transformation at the training data point with respect to a plurality of transformation parameters.

23. A computer program product encoding a computer program for executing on a computer system a computer process, the computer process comprising:

generating derivatives of a nonlinear invariance transformation at a training data point with respect to a transformation parameter, the training data point representing one of a plurality of training patterns; and

generating a classifier representation based on the derivatives for classifying a test pattern in the presence of the nonlinear invariance transformation.

24. The computer program product of claim 23 wherein the computer process further comprises:

classifying the test pattern based on the classifier representation.

25. The computer program product of claim 23 wherein the computer process further comprises:

receiving the plurality of training patterns; and

characterizing one of the training patterns to provide the training data point.

26. The computer program product of claim 23 wherein the computer process further comprises:

classifying the test pattern based on the classifier representation; and

inputting the test pattern to the operation of generating derivatives as a training pattern, responsive to the classifying operation.

27. The computer program product of claim 23 wherein the computer process further comprises:

classifying the test pattern based on the classifier representation to provide a classification signal;

inputting the test pattern to the operation of generating derivatives as a training pattern; and

inputting the classification signal to the operation of generating derivatives in association with the test pattern.

28. The computer program product of claim 23 wherein the non-linear invariant transformation is represented by a Taylor expansion polynomial.

29. The computer program product of claim 23 wherein the nonlinear invariance transformation models a rotation of an individual training pattern.

30. The computer program product of claim 23 wherein the nonlinear invariance transformation models a sheering in an individual training pattern.

31. The computer program product of claim 23 wherein the nonlinear invariance transformation models a translation in an individual training pattern.

32. The computer program product of claim 23 wherein the nonlinear invariance transformation models a change in lighting angle in an individual training pattern.

33. The computer program product of claim 23 wherein the nonlinear invariance transformation models a change in brightness in an individual training pattern.

34. The computer program product of claim 23 wherein the nonlinear invariance transformation models a scaling of an individual training pattern.

35. The computer program product of claim 23 wherein the nonlinear invariance transformation models a change in line thickness in an individual training pattern.

36. The computer program product of claim 23 wherein the nonlinear invariance transformation models a change in frequency composition of an individual training pattern.

37. The computer program product of claim 23 wherein the nonlinear invariance transformation models a change in duration of an individual training pattern.

38. The computer program product of claim 23 wherein the test pattern includes an image.

39. The computer program product of claim 23 wherein the test pattern includes an audio input.

40. The computer program product of claim 23 wherein the test pattern includes a handwriting pattern.

41. The computer program product of claim 23 wherein the test pattern includes a time series.

42. The computer program product of claim 23 wherein the computer process further comprises:

restricting a range of the transformation parameter to a closed interval on a line of real numbers.

43. The computer program product of claim 23 wherein the computer process further comprises:

representing a scalar product of the classifier representation with the derivatives of the nonlinear invariance transformation at the training data point with respect to the transformation parameter by a nonlinear positive definite real-valued kernel function.

44. The computer program product of claim 23 wherein the operation of generating derivatives comprises:

generating derivatives of the nonlinear invariance transformation at the training data point with respect to a plurality of transformation parameters.

45. A system comprising:

a derivative generator generating derivatives of a nonlinear invariance transformation at a training data point with respect to a transformation parameter, the training data point representing one of a plurality of training patterns; and

a classifier representation generator generating a classifier representation based on the derivatives for classifying a test pattern in the presence of the nonlinear invariance transformation.

46. The system of claim 45 further comprising:

a classifier classifying the test pattern based on the classifier representation.

a training data characterizer receiving the plurality of training patterns and characterizing one of the training patterns to provide the training data point.

47. The system of claim 45 wherein the derivative generator inputs the test pattern as a training pattern.

48. The system of claim 45 further comprising:

a classifier classifying the test pattern based on the classifier representation to provide a classification signal, wherein the derivative generator inputs the test pattern as a training pattern and inputs the classification signal in association with the test pattern.

49. The system of claim 45 wherein the non-linear invariant transformation is represented by a Taylor expansion polynomial.

50. The system of claim 45 wherein the test pattern includes an image.

51. The system of claim 45 wherein the test pattern includes an audio input.

52. The system of claim 45 wherein the test pattern includes a handwriting pattern.

53. The system of claim 45 wherein the test pattern includes a time series.

54. The system of claim 45 wherein a range of the transformation parameter is restricted to a closed interval on a line of real numbers.

55. The system of claim 45 wherein a nonlinear positive definite real-valued kernel function represents a scalar product of the classifier representation with the derivatives of the nonlinear invariance transformation at the training data point with respect to the transformation parameter.

56. The system of claim 45 wherein the classifier representation generator generates derivatives of the nonlinear invariance transformation at the training data point with respect to a plurality of transformation parameters.

57. A method comprising:

characterizing a plurality of training patterns, each training pattern corresponding to a training data point in a feature space;

determining a classification for each training pattern;

generating derivatives of a nonlinear invariance transformation at individual training data points with respect to a transformation parameter; and

generating an optimized weight vector, based on the derivatives and the classification of each training pattern, for classifying a test pattern in the presence of the nonlinear invariance transformation.

58. The method of claim 57 further comprising:

classifying the test pattern based on the optimized weight vector.

59. The method of claim 57 further comprising:

classifying the test pattern based on the optimized weight vector to provide a classification signal; and

inputting the test pattern to the operation of generating derivatives as a training pattern, responsive to the classifying operation.

60. The method of claim 57 further comprising:

classifying the test pattern based on the optimized weight vector to provide a classification signal;

inputting the test pattern to the operation of generating derivatives as a training pattern; and

inputting the classification signal to the operation of generating derivatives in association with the test pattern.

61. The method of claim 57 wherein the non-linear invariant transformation is represented by a Taylor expansion polynomial.

62. A computer program product encoding a computer program for executing on a computer system a computer process, the computer process comprising:

characterizing a plurality of training patterns, each training pattern corresponding to a training data point in a feature space;

determining a classification for each training pattern;

generating derivatives of a nonlinear invariance transformation at individual training data points with respect to a transformation parameter; and

generating an optimized weight vector, based on the derivatives and the classification of each training pattern, for classifying a test pattern in the presence of the nonlinear invariance transformation.

63. The computer program product of claim 62 wherein the computer process further comprises:

classifying the test pattern based on the optimized weight vector.

64. The computer program product of claim 62 wherein the computer process further comprises:

characterizing one of the training patterns to provide the training data point.

65. The computer program product of claim 62 wherein the computer process further comprises:

classifying the test pattern based on the optimized weight vector; and

inputting the test pattern to the operation of generating derivatives as a training pattern, responsive to the classifying operation.

66. The computer program product of claim 62 wherein the computer process further comprises:

classifying the test pattern based on the optimized weight vector to provide a classification signal;

inputting the test pattern to the operation of generating derivatives as a training pattern; and

inputting the classification signal to the operation of generating derivatives in association with the test pattern.

67. The computer program product of claim 62 wherein the non-linear invariant transformation is represented by a Taylor expansion polynomial.

68. A system comprising:

a training data characterizer characterizing a plurality of training patterns, each training pattern corresponding to a training data point in a feature space and determining a classification for each training pattern;

a derivative generator generating derivatives of a nonlinear invariance transformation at individual training data points with respect to a transformation parameter; and

a classifier representation generator generating an optimized weight vector, based on the derivatives and the classification of each training pattern, for classifying a test pattern in the presence of the nonlinear invariance transformation.

69. The system of claim 68 further comprising:

a classifier classifying the test pattern based on the classifier representation.

70. The system of claim 68 further comprising:

a training data characterizer receiving the plurality of training patterns and characterizing one of the training patterns to provide the training data point.

71. The system of claim 68 wherein the derivative generator inputs the test pattern as a training pattern.

72. The system of claim 68 further comprising:

a classifier classifying the test pattern based on the classifier representation to provide a classification signal, wherein the derivative generator inputs the test

pattern as a training pattern and inputs the classification signal in association with the test pattern.

73. The system of claim 68 wherein the non-linear invariant transformation is represented by a Taylor expansion polynomial.